Issued May 31, 1910.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 123.

A. D. MELVIN, CHIEF OF BUREAU.

THE INFLUENCE OF LACTIC ACID ON THE QUALITY OF CHEESE OF THE CHEDDAR TYPE.

BY

C. F. DOANE,
Assistant Dairyman, Dairy Division.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., March 14, 1910.

Sir: I have the honor to transmit the accompanying manuscript of an article entitled "The Influence of Lactic Acid on the Quality of Cheese of the Cheddar Type," by C. F. Doane, of the Dairy Division of this Bureau. Mr. Doane has for some time been stationed at one of the principal cheese-making centers of the country, carrying on work connected with the manufacture and storage of cheese under practical conditions. The experiments described in the present paper have resulted in establishing data which are contrary to the usual practice of factories producing the Cheddar type of cheese, and are therefore calculated to be of value to this section of the cheese-making industry. I recommend the publication of the article in the bulletin series of this Bureau.

Very respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE INFLUENCE OF LACTIC ACID ON THE QUALITY OF CHEESE OF THE CHEDDAR TYPE.

INTRODUCTION.

The relation of lactic acid to the science of cheese making, particularly its action under varying conditions, and the necessity, or otherwise, for its development during the process of manufacture, are among the greatest unsolved problems connected with the dairy industry.

In the making of the Cheddar type of cheese at the present time the expert cheese maker is chiefly concerned with this development of lactic acid, and his entire ability is exerted to secure a uniformity of cooking with the development of the acid. This is desired because it is believed that a maximum quantity of acid is necessary for the best results. This maximum development is determined by the amount of acid that the curd will stand in the whey at the time of drawing the latter without subsequent injury to the texture and the color of the cheese. The best cheese makers are agreed, almost without exception, that on this development of acid depends to a great extent the delicate flavor that the best cheese should have, also, the desired closeness of body, as well as some of the qualities of texture found in the best cheese. Under the present conditions, therefore, there is ample opportunity for the exhibition of skill in handling the milk and the curd, since the attainment of even a small degree of success in securing uniformity of the different processes under varying conditions comes only with long practice and keen observation.

LACTIC-ACID PROBLEMS IN CHEESE MAKING.

There is undoubtedly much yet to be learned concerning the development of lactic acid and its effects in cheese making. One apparent inconsistency lies in the differing effects of the lactic acid which is developed before, as compared with that which is developed after, the whey is drawn. It it well known that the development of acid in the whey beyond approximately 0.2 per cent will

result in an acid cheese, although a slight variation from this will depend upon whether the milk is working fast or slow. A high-acid condition has a decidedly injurious effect on the texture and the color of the cheese, and the greater the development of acid in the whey beyond the above limit the more pronounced is the injury. On the other hand, after the whey is drawn and the curd is put on the rack, the acid may develop until the expressed whey shows a full 1 per cent, or even more, without any injury to texture or color. This would certainly appear to be inconsistent. In both cases the acid formed is evidently lactic acid. In both cases the acid is formed inside of the curd particles, as the greater part of the bacteria are carried down into the curd after setting the milk and cutting the curd,[a] and the acid is formed in the curd and expelled into the whey. We have, then, in each case a process of acid formation operating under such similar conditions as to be apparently identical, yet the results are radically different. While in the whey a development of 0.3 per cent of lactic acid will practically ruin the commercial value of the cheese, yet in the matted curd more than three times this quantity may develop with what most cheese makers believe to be a benefit, and certainly without apparent injury.

In the best present-day practice in cheese making there is an attempt to develop all the acid possible without injury to the texture and color of the product. To begin with, a maximum amount of acid is developed in the whey, and finally the curd is allowed to remain on the rack until all the acid that will develop in a practicable length of time is obtained. But while there are many positive opinions in regard to the good results of this method, there is but little accurate knowledge. The effect of acid on flavor is not known, and, contrary to general opinion, a glance at some of the tables included in this paper will show that a flat or low flavor may be found in a high-acid cheese. Again, the actual effects of a so-called proper development of acid on the closeness or the texture of the cheese is not known. The desired characteristics of texture, body, and flavor may be found, and have been found on numberless occasions, when the curd has been worked through comparatively sweet.

However, we know beyond doubt that a high acid development in the whey will injure the resulting product. Furthermore, we have very good reason to believe that a high acid development in the curd made from so-called gassy milk is necessary to overcome the gas, and it may at the same time prevent a full development of the undesirable flavors attending gassy curds.

[a] J. L. Sammis. Factors controlling the moisture content of cheese curds. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 122.

TABLE 1.—*Details of storage experiments showing inferiority of high-acid cheese.*

No. of cheese.	Storage temperature[a] and age of cheese when stored.	Numerical score.					Descriptive score.		
		Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.	Color.
1N2	32° room, at once	21⅓	19½	7	10	57⅞	Tainted, sweet	Curdy, stiff	Mottled.
2N1	Ripened in curing room	23½	19½	11½	10	64	Acid taint	Pasty, loose	Acid cut.
2N2	32° room, at once	22⅔	19½	8½	10	60½	Sour	Stiff, gritty	Do.
2N3	40° room, at once	24	20⅔	9⅔	10	64½	....do	....do	Do.
3N2	32° room, at once	26	24⅔	12	10	72⅔	Fruity	Short, salvy	Do.
3O2	32° room, 1 week	23	19	13	10	65	Tainted	Curdy, short	Do.
4N3	40° room, at once	27½	25	14	10	76½	Fruity, flat	Salvy	Do.
4O2	32° room, 1 week	28½	24½	12	10	74⅝	....do	....do	Do.
5N2	32° room, at once	37½	26⅔	15	10	89	Sweet	....do	Straight.
5O2	32° room, 1 week	36½	24½	15	10	85⅝	....do	....do	Do.
5O3	40° room, 1 week	34⅔	22	15	10	81⅔	Sweet, tainted	Mealy, loose	Acid cut.
6N2	32° room, at once	31	22	15	10	78	Tainted, bitter	Salvy	
6O3	40° room, 1 week	35	24	15	10	84	....do	Smooth	
7N2	32° room, at once	32½	26⅝	15	10	84⅛	Tainted, barn	....do	
7N3	40° room, at once	32	26½	15	10	83½	Tainted slightly	....do	
7O3	40° room, 1 week	36⅔	26	15	10	87⅔	....do	....do	
8N2	32° room, at once	33⅓	22½	15	10	80⅝	Sweet	Gritty	
8O3	40° room, 1 week	31	24	15	10	80	....do	Weak	
9N2	32° room, at once	32⅔	21⅔	8⅔	10	73⅛	Tainted, weedy	Mealy	Acid cut.
9N3	40° room, at once	32	22	8⅔	10	72⅔	Bitter	....do	Do.
9O2	32° room, 1 week	32	23⅔	9½	10	75	Sweet, bitter	....do	Do.
10N2	32° room, at once	29½	24	13½	10	76⅔	Tainted	Short, weak	
10N3	40° room, at once	31⅔	24	12	10	77⅔	....do	....do	
10O2	32° room, 1 week	30	22⅔	10½	10	73	....do	....do	Do.
11N2	32° room, at once	37⅔	26	15	10	88⅔	Weedy, flat	Coarse	
11O2	32° room, 1 week	37⅔	24	15	10	86⅔	Acid taint	Gritty	
11N3	40° room, at once	40⅔	29½	14	10	94	Flat	....do	
11O3	32° room, 1 week	36⅔	24½	15	10	85⅔	Cowy, weedy	....do	
12N2	32° room, at once	36	26⅔	15	10	87⅔	Sweet, cowy	Smooth	Straight.
12N3	40° room, at once	33⅓	24⅔	13½	10	81½	....do	Gritty	Acid cut.
12O2	32° room, 1 week	36½	25	15	10	86½	Sweet	....do	Do.
12O3	40° room, 1 week	29½	24⅔	13	10	77	....do	....do	Do.
13N2	32° room, at once	30⅔	26	12½	10	79⅛	Tainted	Smooth	
13N3	40° room, at once	32	24⅔	15	10	81⅔	Tainted, cowy	Loose	
13O2	32° room, 1 week	33⅛	25½	13⅜	10	82⅜	Tainted	....do	
13O3	40° room, 1 week	32⅝	25⅝	15	10	83⅜	....do	....do	
14N2	32° room, at once	30	25	15	10	80	Tainted, flat	Tallowy	Straight.

[a] Temperatures Fahrenheit.

TABLE 1.—*Details of storage experiments showing inferiority of high-acid cheese*—Continued.

No. of cheese.	Storage temperature[a] and age of cheese when stored.	Numerical score.					Descriptive score.		
		Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.	Color.
14N3	40° room, at once	28⅛	22⅔	12⅓	10	73⅛	Tainted	Salvy, mealy	Acid cut.
14O2	32° room, 1 week	32⅓	24⅔	14	10	81	do	do	Do.
14O3	40° room, 1 week	31	23⅓	14	10	80⅓	Tainted, bitter	do	Do.
15N2	32° room, at once	31	26	15	10	82	Sweet, tainted	Weak, smooth	Straight.
15N3	40° room, at once	26⅛	25	15	10	76⅓	Sweet	do	Do.
15O2	32° room, 1 week	29⅛	27	11	10	77⅓	Bitter, sweet	Weak, mealy	Acid cut.
16J2	32° room, immediately	31⅔	23⅓	14⅔	10	79⅔	Tainted, flat	Weak	Straight.
16J3	40° room, immediately	29⅔	23⅔	14	10	77⅓	do	Pasty	Do.
16K2	32° room, 4 days	27⅓	22⅔	11⅔	10	72	Tainted	Short	Acid cut.
16K3	40° room, 4 days	26⅓	20	10	10	66⅓	Bitter, sour	Short, mealy	Do.
16L2	32° room, 1 week	27⅓	20	11	10	68⅓	Tainted, sour	do	Do.
16L3	40° room, 1 week	26	21⅓	11	10	68⅓	do	do	Do.
16M2	32° room, 2 weeks	27	22	13	10	72	do	do	Do.
16M3	40° room, 2 weeks	27⅓	22	11⅔	10	71	do	do	Do.
17J2	32° room, at once	28⅔	25	14⅓	10	78	Tainted	Stiff	
17J3	40° room, at once	29	21	10	10	70	do	do	Wavy.
17M3	40° room, 2 weeks	26⅔	20⅓	13⅓	10	70⅓	do	do	Mottled.
18J2	32° room, at once	35⅓	26	15	10	86⅓	Flat	Smooth, stiff	
18J3	40° room, at once	35⅔	27⅔	15	10	88⅓	Flat, sour	Smooth	
18L2	32° room, 1 week	35⅔	25⅓	15	10	86	Flat	do	
18L3	40° room, 1 week	34⅓	26	15	10	85⅔	Sweet, sour	Smooth, stiff	
18M3	40° room, 2 weeks	32⅓	24⅓	15	10	81⅔	Sweet, tainted	Stiff, gritty, Swiss holes	
19J2	32° room, at once	31⅔	27	15	10	83⅔	Flat, low	Mechanical holes	
19J3	40° room, at once	31⅓	25⅓	15	10	81⅔	Flat, tainted	Smooth, stiff	
19L3	40° room, 1 week	30⅓	23⅓	15	10	78⅓	Tainted, cowy	Pasty	Acid cut.
19M3	40° room, 2 weeks	27⅓	24⅔	14	10	76	Sweet, tainted	Stiff, gritty	Do.
20J2	32° room, at once	32	25⅔	15	10	82⅓	Flat	Stiff	
20J3	40° room, at once	26	22⅓	15	10	73⅓	Tainted	do	
20L2	32° room, 1 week	27⅓	23	15	10	75⅓	do	do	
20M3	40° room, 2 weeks	25	23	13⅓	10	71⅓	do	Lumpy, stiff	Do.
21J2	32° room, at once	35	27⅓	15	10	87⅓	do	Stiff	
21J3	40° room, at once	34⅔	27	15	10	86⅔	Tainted, flat		
21L2	32° room, 1 week	30⅔	26⅔	15	10	88⅓	do	Stiff, smooth	
21M3	40° room, 2 weeks	31	25⅓	15	10	81⅓	do	do	
22J2	32° room, at once	36	27⅓	15	10	88⅓	Flat	Smooth	
22J3	40° room, at once	34	26⅔	15	10	85⅓	do	Smooth, stiff	Straight.
22L2	32° room, 1 week	31	24	14⅓	10	79⅓	Tainted	Mealy, stiff	Acid cut.
22L3	40° room, 1 week	30⅔	23⅓	12	10	76⅓	do	Mealy	Do.
22M3	40° room, 2 weeks	30⅔	26	9	10	75⅔	do	do	Do.

23J2	32° room, at once	27¼	21½	13	10	71⅞	Acid, badly tainted ..... do	Do.
23M3	40° room, 2 weeks	24	20	11	10	65	..... do ..... do	Do.
24J2	32° room, at once	29⅝	26⅜	12	10	78¼	Acid, tainted ..... do	Do.
24L2	32° room, 1 week	29	23⅞	13	10	75¼	..... do ..... do	Do.
24M3	40° room, 2 weeks	26	20⅝	10	10	66⅝	..... do ..... do	Do.
25J2	32° room, at once	29¼	20¾	14	10	73⅜	Bitter, flat ..... do	Do.
25J3	40° room, at once	26	21	9	10	66	Bitter, tainted ..... do	Do.
25L2	32° room, 1 week	26	20¼	10	10	66¼	Acid, tainted ..... do	Do.
25M3	40° room, 2 weeks	22	18	8	10	58	..... do ..... do	Do.
26J2	32° room, at once	34½	26½	14½	10	85	Tainted, flat ..... Stiff, smooth	
26J3	40° room, at once	33	26⅜	14⅛	10	84	Tainted ..... do	
26K2	32° room, 4 days	32¾	23⅝	15	10	81½	Tainted, flat ..... do	
26K3	40° room, 4 days	34½	24⅜	15	10	84⅝	Tainted ..... Stiff, curdy	
26L2	32° room, 1 week	35⅛	25	15	10	85⅛	..... do ..... Stiff, tough	
26L3	40° room, 1 week	30⅝	24⅝	15	10	80½	..... do ..... Tough	
26M2	32° room, 2 weeks	23½	22½	15	10	70⅔	Badly tainted ..... Stiff, tough	Wavy.
26M3	40° room, 2 weeks	29⅔	24	10⅓	10	74	..... do ..... Stiff	Do.
27J2	32° room, at once	22	19	9	10	60	Sour, tainted ..... Short, mealy	Acid cut.
27J3	40° room, at once	23½	20⅔	9	10	63	..... do ..... do	Do.
27K2	32° room, 4 days	23⅔	20½	9	10	63	..... do ..... do	Do.
27K3	40° room, 4 days	24⅝	20½	11	10	66	..... do ..... Short	Do.
27L2	32° room, 1 week	25⅝	20⅝	10	10	66	..... do ..... Short, mealy	Do.
27L3	40° room, 1 week	24⅔	19⅔	9	10	63⅓	Sour, badly tainted ..... do	Do.
27M2	32° room, 2 weeks	20	19	9	10	58	..... do ..... do	Do.
27M3	40° room, 2 weeks	18	17	7	10	52⅓	..... do ..... do	Do.
28J2	32° room, at once	28	23	11	10	72	Sour, flat ..... do	Do.
28J3	40° room, at once	28	23⅓	12	10	73⅓	..... do ..... do	Do.
28K2	32° room, 4 days	27⅔	22⅝	10	10	70⅓	Acid ..... do	Do.
28K3	40° room, 4 days	26⅔	22⅝	10	10	69	Acid, tainted ..... do	Do.
28L2	32° room, 1 week	26½	22⅔	11	10	70	..... do ..... do	Do.
28L3	40° room, 1 week	27	22¼	10	10	69⅔	..... do ..... do	Do.
28M2	32° room, 2 weeks	23⅔	21⅓	10	10	64⅔	..... do ..... do	Do.
28M3	40° room, 2 weeks	24	20	10	10	64	Acid, tainted, bitter ..... do	Do.
29J2	32° room, at once	28	24⅔	15	10	77⅔	Tainted, sweet ..... Loose, gas holes	
29J3	40° room, at once	28⅔	25	15	10	78⅓	Sweet, bitter ..... Gas holes	
29K2	32° room, 4days	25⅔	24⅝	15	10	75¼	Sweet, tainted ..... do	
29K3	40° room, 4 days	24½	22½	15	10	71⅔	..... do ..... do	
29L2	32° room, 1 week	26⅔	23⅔	15	10	75½	..... do ..... do	
29L3	40° room, 1 week	26¼	23	15	10	74⅓	..... do ..... do	
29M2	32° room, 2 weeks	23	21⅓	15	10	69⅓	..... do ..... do	
29M3	40° room, 2 weeks	23	21¼	15	10	69½	..... do ..... do	
30J2	32° room, at once	33	27⅔	15	10	85⅓	Tainted, flat ..... Smooth	
30J3	40° room, at once	31½	26⅔	15	10	83	..... do ..... Stiff	
30K2	32° room, 4 days	29¼	25	15	10	79½	..... do ..... do	
30K3	40° room, 4 days	29¼	26	15	10	80½	..... do ..... do	
30L2	32° room, 1 week	28¼	25	15	10	78½	..... do ..... Gas holes	
30L3	40° room, 1 week	28¾	24½	15	10	77⅔	..... do ..... do	
30M2	32° room, 2 weeks	29⅔	24½	15	10	79	Tainted ..... do	
30M3	40° room, 2 weeks	26	24	15	10	75	..... do ..... do	
31J2	32° room, at once	33	26⅓	15	10	84½	Tainted, flat ..... Mechanical holes	
31J3	40° room, at once	30¼	26	15	10	81½	..... do ..... do	

[a] Temperatures Fahrenheit.

TABLE 1.—*Details of storage experiments showing inferiority of high-acid cheese*—Continued.

No. of cheese.	Storage temperature[a] and age of cheese when stored.	Numerical score.					Descriptive score.		
		Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.	Color.
31K2	32° room, 4 days	31	27⅓	15	10	83⅓	Tainted, flat	Smooth, mechanical holes	
31K3	40° room, 4 days	28⅓	25	15	10	78⅓	do	Gritty, mechanical holes	
31L2	32° room, 1 week	28	25	15	10	78	do	do	
31L3	40° room, 1 week	26⅔	24⅔	15	10	76⅓	do	Gritty, gas holes	
31M2	32° room, 2 weeks	29	23⅓	15	10	77⅓	Tainted	do	
31M3	40° room, 2 weeks	24⅔	25	15	10	74⅔	do	do	
32J2	32° room, at once	30⅓	27	15	10	82⅓	Tainted, flat	Gas holes, smooth	
32J3	40° room, at once	27⅓	25⅓	15	10	77⅔	do	Short	
32K2	32° room, 4 days	27⅔	25⅓	15	10	78	Tainted	do	
32K3	40° room, 4 days	26⅔	25	14	10	75⅔	do	do	Acid cut.
32L2	32° room, 1 week	26	24⅔	12	10	72⅔	do	do	Do.
32L3	40° room, 1 week	26⅓	24⅔	10	10	71	do	do	Do.
32M2	32° room, 2 weeks	25	23⅔	10	10	68⅔	do	do	Do.
32M3	40° room, 2 weeks	26⅔	23⅔	10	10	70⅓	Tainted, bitter	do	Do.
33J2	32° room, at once	27	24	13	10	74	Tainted, bitter, flat	Short, mealy	Do.
33J3	40° room, at once	28	25	14	10	77	do	do	Do.
33K2	32° room, 4 days	25⅓	22⅔	11	10	69	do	do	Do.
33K3	40° room, 4 days	24⅔	22⅔	12	10	69⅓	Tainted, bitter	do	Do.
33L2	32° room, 1 week	25⅔	23⅓	10½	10	69⅓	do	do	Do.
33L3	40° room, 1 week	26⅔	26	12⅔	10	75⅓	Tainted, sour	do	Do.
33M2	32° room, 2 weeks	23⅔	23⅓	10	10	67	do	do	Do.
33M3	40° room, 2 weeks	24⅔	23⅔	10⅓	10	68⅔	do	do	Do.
34J2	32° room, at once	32	27⅓	14	10	83⅓	Tainted, flat	Smooth	
34J3	40° room, at once	33⅓	27⅔	14	10	85	do	do	
34K2	32° room, 4 days	31⅓	26⅔	14	10	81⅔	do	do	
34K3	40° room, 4 days	31⅓	27⅓	14	10	83	do		
34L2	32° room, 1 week	30⅔	26	14	10	80⅔	do	Pasty, gas holes	
34L3	40° room, 1 week	29	26	14	10	79	Tainted	do	
34M2	32° room, 2 weeks	28⅔	25⅓	14	10	78	do	do	
34M3	40° room, 2 weeks	28⅓	24⅔	14	10	77	do	do	

1. The cheeses which had too much acid are noted as "acid cut" in the column headed "Color."
2. The first figure in the number of the cheese indicates the lot or vat.

[a] Temperatures Fahrenheit.

EFFECT OF HIGH ACIDITY ON QUALITY OF STORAGE CHEESE.

The attention of the writer was called to one phase of this acid question at the time of scoring the cheese in the storage experiments made in the summer of 1906. A representative of the Dairy Division visited a number of cheese factories near Plymouth, Wis., that were having trouble with their product, and secured a quantity of cheese for storage. Most of these lots of cheese turned out to be high acid, and it was noted that where this was the case the quality was so very low as to make it appear that the acid was responsible in part at least for the poor flavor, as well as for the other undesirable characteristics always found in a high-acid cheese.

The cheese in question was obtained for the purpose of determining the effect of storage on different kinds of poor cheese. It was purchased in July and August and was scored in January. The scores are given in Table 1. Because of the large proportion of this cheese that turned out to be high acid the work as planned was not satisfactory, but it did show the tendency to make high-acid cheese when troubles with bad milk are experienced, and it illustrated very well the probable effect of high acid on the quality of the product. There were 34 lots of the cheese, each consisting of 8 cheeses, one-half of which were stored in the 32° F. room at various periods ranging up to two weeks, the other half being similarly placed in the 40° F. room. The average score on flavor for the high-acid cheese was 27, while the average on the normal acid cheese was 31. The comparatively poor flavor of all the high-acid cheese was so marked that all who were connected with the scoring of this cheese noticed it and commented upon it.

The Dairy Division made some high-acid cheese in the summer of 1906 to determine the effects of storage on this quality of product. The cheese was made from exceptionally good milk, and the flavor should have been, in some of the lots at least, above criticism. Nine lots of cheese were made with varying amounts of acid. Quite a wide variation in the percentages of acid was sought, especially at the time the whey was drawn, as the degree of acidity at this period influences the quality of the cheese more than the acidity shown at any other period of its manufacture. The acid at the time of setting was regulated to suit the percentage desired at the time of drawing the whey. The percentages of acid at different stages of manufacture are shown in Table 3.

Eight cheeses were made in each lot. These were stored two at a time—one at 32° F. and the other at 40° F.—at each of the following periods: Fresh from the press, four days old, one week old, and two weeks old. All the cheese was scored by three judges working independently, and Table 2 gives the average scores. Table 4, abstracted

TABLE 2.—*Average scores of cheese, showing influence of high acid.*

No. of cheese.	Storage temperature[a] and age of cheese when stored.	Numerical score.					Descriptive score.		
		Flavor (Max. 45).	Texture (Max. 30).	Color (Max. 15).	Make-up (Max. 10).	Total (Max. 100).	Flavor.	Texture.	Color.
1R2	32° room, at once	31⅜	26½	14	10	82	Tainted, flat	Smooth	Straight.
1R3	40° room, at once	30	25⅝	14	10	80½	Flat, acid	Gritty	Slightly acid cut.
1S2	32° room, 4 days	28⅝	24¼	13	10	76	High acid, tainted	Short, gritty	Wavy.
1S3	40° room, 4 days	27	24½	13	10	74½	Tainted, slight acid	Stiff, gritty	Acid cut.
1T2	32° room, 1 week	26⅔	23⅝	12½	10	72½	Acid, tainted, sweet	Crumbly, mealy	Wavy.
1T3	40° room, 1 week	26	24	12	10	72	Acid, tainted	Mealy, loose	Acid cut.
1U2	32° room, 2 weeks	27½	24⅝	14	10	76	Tainted, acid	Short, stiff	Do.
1U3	40° room, 2 weeks	26⅔	25	14	10	75⅔	Sharp, acid	Stiff, gritty	Do.
2R2	32° room, at once	26	24½	12	10	72½	Acid, tainted	Pasty, gritty	Do.
2T2	32° room, 1 week	24½	23½	10⅔	10	68⅓	do	Mealy, gritty	Do.
2U3	40° room, 2 weeks	24	18¾	11	10	63¾	Acid	Short, mealy	Do.
3R2	32° room, at once	23⅔	22⅓	11	10	67	Acid, tainted	Mealy, short	Do.
3T2	32° room, 1 week	23½	18⅓	9⅔	10	61⅓	Acid	Short, mealy	Do.
3U3	40° room, 2 weeks	21½	17	7⅔	10	56	Acid, taint	Dry, mealy	Do.
4R2	32° room, at once	25	22½	9⅔	10	67	Acid, sour	Short, mealy	Do.
4T2	32° room, 1 week	22⅔	18	8	10	58⅔	Acid, taint, sour	Dry, mealy	Do.
4U3	40° room, 2 weeks	22	18¼	8	10	58½	Sour, acid	do	Do.
5R2	32° room, at once	20	14	5⅔	10	49⅔	Acid, taint, sour	do	Do.
5U3	40° room, 2 weeks	18½	14⅓	5	10	47⅔	Acid, taint	Short, loose	Do.
6R2	32° room, at once	28⅔	25	11	10	74⅓	Acid, flat	Pasty, weak	Do.
6T2	32° room, 1 week	26	24	10	10	70	Acid, tainted	Short, mealy	Do.
6U3	40° room, 2 weeks	25	21⅓	9	10	65⅓	do	Mealy, gritty	Do.
7R2	32° room, at once	26⅔	25	11	10	72⅔	Acid	Pasty	Do.
7T2	32° room, 1 week	25½	23	10¼	10	68⅔	Acid, tainted	Pasty, mealy	Do.
7U3	40° room, 2 weeks	26½	22½	10	10	68⅔	Acid, taint	Mealy, gritty	Do.
8R2	32° room, at once	27⅔	23½	10⅔	10	71⅔	Acid	Pasty, gritty	Do.
8T2	32° room, 1 week	27	24	10¼	10	71¼	do	Pasty, mealy	Do.
8U3	40° room, 2 weeks	24½	21⅓	12	10	67⅔	Sour, tainted	Dry, mealy	Do.
9R2	32° room, at once	26⅔	24	10⅓	10	71	Acid, tainted	Pasty	Do.
9T2	32° room, 1 week	25⅓	22	9	10	66⅓	Acid, sour	Dry, mealy	Do.
9U3	40° room, 2 weeks	24⅓	21⅔	9	10	65	Acid, tainted	Mealy, gritty	Do.

The first figure indicates the lot; thus all cheeses with No. 1 came from the same vat.

[a] Temperatures Fahrenheit.

from Table 2, and figure 1 are arranged to show more clearly the relation of the numerical score to the acidity. Not all the scores are given, but those omitted are in line with those given. Enough are given to show conclusively the effect of the high acid on the cheese.

TABLE 3.—*Acidity at stated periods of high-acid cheese used in storage experiments and scored in Table 2.*

No. of lot.	Acidity when set.	Acidity when cut.	Acidity when drawn.
	Per cent.	*Per cent.*	*Per cent.*
1	0.175	0.120	0.207
2	.175	.....	.229
3	.185	.....	.240
4	.195	.....	.215
5	.260	.184	.303
6	.200	.145	.225
7	.175	.....	.220
8	.182	.....	.211
9	.170	.120	.220

TABLE 4.—*Relation of the numerical score to the acidity of cheese described in Table 2.*

Number of lot.	Acidity.	32° room, at once.			32° room, one week.			40° room, two weeks.		
		Flavor.	Texture.	Total.	Flavor.	Texture.	Total.	Flavor.	Texture.	Total.
	Per ct.									
1	0.207	31⅔	26⅓	82	26⅔	23⅔	72½	26⅔	25	75⅔
8	.211	27⅔	23⅓	71⅔	27	24	71⅓	24⅓	21⅓	67⅔
4	.215	25	22⅓	67	22⅔	18	58⅔	22	18½	58½
7	.220	26⅔	25	72⅔	25½	23	68⅔	26½	22½	68⅔
9	.220	26⅔	24	71	25½	22	66½	24⅓	21⅔	65
6	.225	28⅔	25⅓	74⅔	26	24	70	25	21⅓	65⅓
2	.229	26½	24⅓	72⅓	24⅓	23⅓	68⅓	26⅔	18⅓	63⅓
3	.240	23⅔	22⅓	67	23½	18⅓	61⅓	21⅓	17	56
5	.303	20	14	49⅔	.....	.....	.....	18⅓	14⅛	47⅔

It has already been stated that the above cheese was made as far as could be judged from perfect milk and that the curds worked through in excellent shape. At least a few cheeses should have been of excellent quality; but it appears that the quality was injured in about the same proportion as the amount of acid developed. The cheese in lot 1 was made with acid very slightly in excess of normal, and the cheese from this lot that was placed in the 32° room at once scored 82, while the similarly treated cheese in lot 5 was made with much too high a development of acid and scored a fraction less than 50. It is probable that cheese made from good milk would never score as low as 50 points or as low as 20 points in flavor if it had been treated normally in all stages of making and curing. Hence it would appear very probable that the high-acid development was responsible in part, at least, for the poor flavor. These results were so contrary to all belief and teaching that it was thought desirable to make some

accurate comparative tests that would settle the question beyond controversy. For this purpose the author spent some time at a factory near Plymouth, Wis., and carried out the experiments described in the following pages.

EXPERIMENTAL WORK TO TEST EFFECT OF ACID ON FLAVOR.

Sixteen lots of cheese were made for these experiments. Two lots were made each day from vats of divided milk so as to have identical conditions as regards quality of milk. One of these lots was worked up with just sufficient acid in the whey to make a light-acid cheese, the other lot being worked up on the same day in the regular way for that factory. The cheese maker in charge of this factory set his

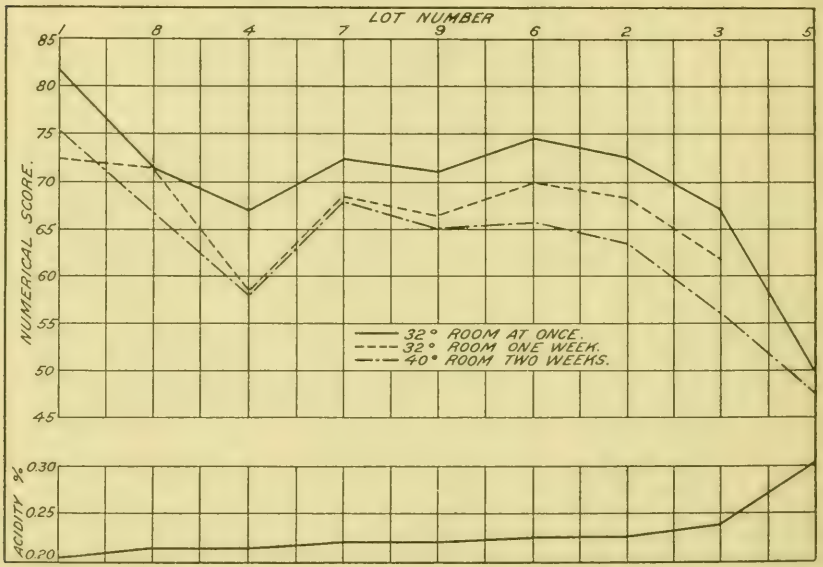

FIG. 1.—Diagram showing relation of acidity to score of cheese at various periods and temperatures.

milk and drew the whey somewhat sweeter than is customary among the best cheese makers; but the curd was allowed to develop the acid on the rack until all danger of gas had passed. Table 5 shows some of the details of the manufacture of each lot.

The cheese was made during the first half of September, 1907, and each lot was held in the factory curing room one week before being placed in storage. The storage room was held at about 33° F. The cheese was scored in the middle of January, 1908, by J. W. Moore and Robert McAdam, of the Dairy Division, both experienced cheese makers and judges. The average score of each cheese is shown in Table 6, and the relation of the numerical score to the acidity is graphically shown in figure 2.

TABLE 5.—*Details of manufacture of cheese for test of high acid on flavor.*

Lot.	Time set.	Acidity when set.	Time cut.	Time drawn.	Acidity when drawn.	Curd ground.	Curd salted.	Remarks.
	a. m.	*Per cent.*	*a. m.*	*a. m.*	*Per cent.*	*p. m.*	*p. m.*	
1, acid	7.52	0.17	8.25	11.00	0.23	1.15	1.40	Curd firm; few pin holes; bad flavor.
1, sweet	7.45	.17	8.25	10.00	.17	12.30	2.15	Numerous pin holes; bad flavor, same as acid vat.
2, acid	8.30	.20	8.50	9.55	.20	12.20	1.30	Good curd.
2, sweet	7.20	.17	7.55	9.15	.15	12.30	1.30	Do.
3, acid	8.10	.20	8.30	9.55	.20	11.45	12.30	Good curd; slight taint.
3, sweet	7.40	.175	8.20	9.45	.16	12.00	12.30	Few pin holes; slight taint.
4, acid	7.50	.20	8.20	9.35	.21	12.05	1.00	Gassy.
4, sweet	7.40	.17	8.20	9.45	.18	12.45	1.30	Do.
5, acid	10.00	.20	10.20	11.55	.21	2.20	3.30	Slight taint; pin holes.
5, sweet	8.50	.17	8.45	10.40	.16	1.00	2.30	Do.
6, acid	8.40	.20	9.02	10.45	.20	1.00	2.15	Do.
6, sweet	8.00	.19	8.30	10.30	.16	12.40	2.00	Do.
7, acid	8.52	.20	9.15	10.45	.20	1.00	2.00	Slight taint.
7, sweet	8.10	.18	8.50	10.50	.18	2.00	3.00	Slight taint; few pin holes.
8, acid	9.20	.145	9.40	11.30	.19	1.30	2.30	Slight taint; pin holes.
8, sweet	7.45	.175	8.32	10.45	.16	1.15	2.00	Do.

TABLE 6.—*Average scores of cheese described in Table 5.*

Lot.	Numerical score.						Descriptive score.		
	Acidity when drawn.	Flavor (max. 45).	Texture (max. 30).	Color (max. 15).	Make-up (max. 10).	Total (max. 100).	Flavor.	Texture.	Color.
	Per ct.								
1, acid	0.23	35½	23½	13¼	10	82½	Sour whey, sweet	Coarse, mealy, stiff.	Acid cut.
1, sweet	.17	39	28	15	10	92	Sweet	Mechanical holes	Straight.
2, acid	.20	34	24½	13¼	10	81¾	Sour, bitter, unclean.	Short, pasty, mealy.	Acid cut.
2, sweet	.15	39	27½	15	10	91½	Unclean	Mechanical holes	Straight.
3, acid	.20	33½	23	13¼	10	79¾	Very unclean, sweet, sour whey.	Crumbly, mealy	Acid cut.
3, sweet	.16	39¾	27½	15	10	92	Trifle sweet	Coarse	Straight.
4, acid	.21	37½	24¾	13½	10	85½	Unclean, sweet	Short, mealy	Acid cut, slightly.
4, sweet	.18	39¾	27¾	15	10	92½	Sweet	Coarse	Straight.
5, acid	.21	36	25	13¾	10	84¾	Sour whey, bitter, sweet.	Crumbly, mealy, salvy.	Acid cut.
5, sweet	.16	39½	27	15	10	91½	Slightly sweet	Uneven	Straight.
6, acid	.20	34½	24	12¼	10	81¾	Sour whey, bitter, sweet.	Mealy, soggy	Acid cut.
6, sweet	.16	38½	27¾	14¾	10	91	Sweet	Uneven	Slightly faded.
7, acid	.20	36¾	26½	14	10	86¾	Fermented, sour whey, bitter, sweet.	Short, mealy	Acid cut.
7, sweet	.18	38¾	27¼	15	10	91	Tainted, sweet	Weak	Straight.
8, acid	.19	36¼	25½	14	10	86	Sour, bitter, sweet	Crumbly, mealy	Acid cut.
8, sweet	.16	38¾	28¼	15	10	92			Straight.

Average score on flavor of cheese made with normal acid, 39.
Average score on flavor of cheese made with high acid, 35.5.

As will be noted from Table 6, the milk was not perfect at any time during which the experimental cheese was made, neither was it very bad, and there was no difficulty in making a cheese that commanded full market price. There was a slight taint, also a few pin holes that worked out easily in the matted curd. It was perhaps unfortunate in some respects that the milk was not perfect for a few of the lots.

But the results of the experiment are so positive that it can not be considered otherwise than conclusive.

A study of the numerical and descriptive scores in Table 6 shows that high acid has a markedly injurious influence on the flavor. The bad flavors in the cheese made up sweet were in every case less pronounced than in that of the same lot which was made up acid. In addition other bad flavors appeared in the acid cheese that were not apparent in the cheese made normally. The sweet or fruity flavor that was noticed in all the cheese was more pronounced in the high acid than in the normal cheese of the same day. In five out of the eight lots a bitter flavor in the acid cheese appeared that was not noticeable in the normal cheese of the same day. A sour or old whey flavor appeared in most of the high-acid cheese.

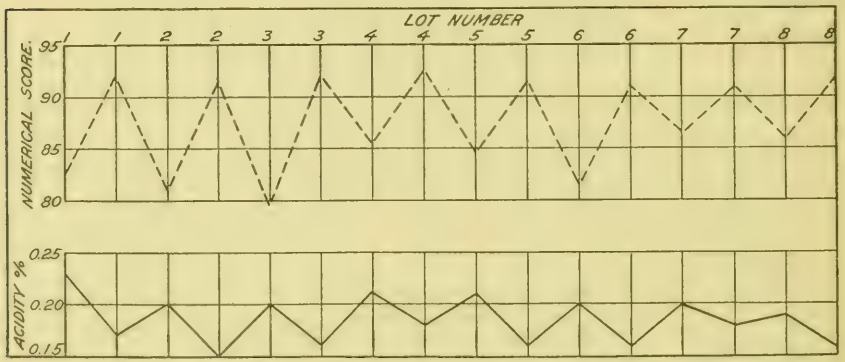

FIG. 2.—Diagram showing relation of acidity to score of high-acid and normal cheese.

RESULTS OF EXPERIMENTS CONTRARY TO GENERAL PRACTICE.

These results are certainly very radical in view of the belief of cheese makers and the teaching of experts to the contrary. The great majority of cheese makers believe that a high development of acid is an antidote for bad flavors of all kinds, and that it is about the only means they have of fighting bad flavors as well as gas. Whenever a period of bad milk comes and the product is off flavored or gassy, the effort has always been made to develop a maximum of acid in the whey as a preventive of the trouble. It has, in fact, usually been considered advisable, where the trouble has been pronounced, to make a slightly high-acid cheese, as the high acid has been considered the less of the two evils. This practice is taught by dairy instructors and recommended by many cheese dealers who act as advisers to the cheese makers from whom they buy. The result has usually been that after a few lots of poor cheese were made at a factory a period of high-acid cheese followed. The foregoing experi-

ments prove that this tendency to develop excessive acid is poor policy. In fact, instead of minimizing the faults it makes them more pronounced, as well as adding new faults to the product.

It is universally believed and taught that a maximum development of acid in the whey is necessary for a satisfactory and maximum development of acid in the matted curd. Dean,[a] in some of his work, seemed to show that the curd was ready for grinding and for the press at the same time regardless of the percentage of acidity at which the milk was set or the whey drawn, vats of divided milk being used for the experiments. In view of the fact that the bacteria are held within the curd particles and the acid is consequently developed in the curd, we have no reason to believe that this development would not go on as fast in the matted curd as in the whey. This would appear to be much more reasonable than the old idea that a maximum development of acid in the whey was necessary to hurry the process.

While a high acidity is needed to exclude undesirable forms of bacteria and give the cheese its desired characteristics, this high acidity can develop in the matted curd. That there is no virtue in a high development of acid in the whey can be seen from Table 5. The taint and the gas were as bad in the curd allowed to remain in the whey until a high acid was developed as they were in the curds from the comparatively sweet whey. The development of high acid in the whey did not have any effect on the growth of injurious bacteria, as far as could be judged from the product. The maximum amount of acid in the whey at time of drawing is about 0.2 per cent, and this is generally considered to be insufficient to check most of the injurious bacteria. It is the comparatively high-acid development which takes place in the matted curd that holds these bacteria in check.

From all this evidence there is but one conclusion to be drawn, namely, that the teaching which led to a maximum development of acid in the whey was wrong. The high acid developed in the whey is likely to cause much injury, and from the evidence at hand it does no good. With our present knowledge, however, it can hardly be advised to go to the other extreme and run the whey as sweet as possible, but it is certainly evident that the whey should be run sufficiently sweet to leave no possibility of making a high-acid cheese.

An interesting feature of the results of the experiments shown in Tables 1 and 2 is seen in the lots where only part of the cheese turned out to be high acid. The cheeses in those lots that were placed in storage direct from the press showed no evidence of high acid, while those that remained in the factory curing room for a time before going

[a] Twenty-second Annual Report, Ontario Agricultural College, 1896, p. 54.

into storage were injured in texture and color. The point in this connection lies in the fact that the cheese that was injured in texture and color was likewise injured in flavor. Whether the low score on flavor was simply coincident with the low score on texture and color and due to the longer time that the cheese was held out of storage, or whether there is some unexplained connection between the injury in texture and the injury to flavor, might seem open to question. It would appear that the former was the case in part. If the latter be true it must be considered that the point in acidity which injures the texture also injures the flavor. There are reasons to believe that this is true, or at least that the point of acidity at which the flavor is injured and the point at which the texture is injured are not very far apart.

There is therefore a question in connection with this which may be investigated with profit. Whey can be drawn with 0.2 per cent of acid without injury to the texture of the curd. Any acid above this evidently injures both texture and flavor. Does the injury to texture and to flavor begin at the same point in acidity, or does injury to flavor begin with a lower acidity than 0.2 per cent?

THE USE OF STARTER IN MILK.

Nothing in this discussion should be interpreted as being opposed to the use of a good starter in the milk before setting. The development of acid is, according to our present knowledge on the subject, necessary to overcome the growth of gas-producing and other undesirable forms of bacteria. Bacteriological investigations have shown that if there is a sufficient number of lactic-acid bacteria as compared with the other kinds, the lactic-acid bacteria increase to the partial exclusion of many other kinds. When the lactic acid has developed to a relatively high degree it makes the milk or the curd an unfavorable place for many kinds of bacteria to grow. The starter can be added usually without any danger of increasing the acidity to a point where it will be difficult to cook to a proper degree of firmness before too high acidity has developed in the whey.

EFFECT OF EARLY STORAGE ON ACID CHEESE.

This work may be considered a continuation of previous work carried on by the Dairy Division at Plymouth during the summer of 1905.[a] It was planned to determine definitely some of the results which showed incidentally in the previous work. The main point which it was desired to cover was the effect of low storage temperatures on high-acid cheese.

[a] Bureau of Animal Industry Bulletin 85.

In the report on the previous storage work at Plymouth attention was called to the fact that in two or three lots of cheese used in the tests the cheese which was left in the factory curing room for from one to two weeks at a temperature of from 55° to 70° F. showed decidedly too much acid, almost a so-called "dead sour" in one case. The ones from the same lots (including the dead-sour lot) which went directly from the hoop into the rooms held at 32° and 40° F. were very slightly acid, in fact showed so little evidence of too much acid that the selling price was not affected in the least. This was a decidedly interesting point, and as practically all cheese dealers held entirely opposite views, a thorough demonstration of the results obtained would be of economic importance as well as of scientific value.

At the present time most of the cheese dealers protest against receiving a cheese under one week of age, because in a young cheese too much acid can not be readily detected. If it can be satisfactorily shown that a cheese which does not show too much acid at the time it goes into storage will come out of storage in good condition the objection on the part of the dealers to receiving very fresh goods would be entirely overcome, so far as high acid is concerned.

A reference to Tables 2 and 3, which give details of experiments intended to cover this point, shows that the sooner a high-acid cheese is placed in cold storage the better it is for the cheese. This is borne out by the scoring of the cheese in lot 1. The cheese that was left in the factory curing room for a week before going into storage showed decidedly acid and was badly injured, while that which went directly into storage was not injured in either texture or color. In all the other lots the scores show that the effect of the high acid was minimized by early storage.

The favorable effect that immediate storage has on high-acid cheese was very clearly demonstrated also in Table 1. Lots 4, 12, 14, 15, 16, 19, 20, 22, 26, and 31 described in this table were evidently made up with too much acid. The portions of these lots that remained in the factory curing rooms for any length of time after making showed defects in texture and color, while those that went directly into storage were not injured in the least. The average score on the high-acid lots of the cheese just referred to that went into storage at once was 78, while the average score of the lots that went into storage in one week was 74. Similarly the scores of the lots in Table 2 were 72.5 and 67.2, respectively.

In so-called dead-sour cheese early storage will minimize the damage, but it is not a cure, as is evidenced by lot 5 in Table 3. However, the buyers can usually detect these very sour cheeses at an early age, and there is no danger of deception. From these experiments

it would appear that the objection on the part of the buyers to handling a cheese direct from the press is not well founded.

CONCLUSIONS.

1. In the process of making Cheddar cheese a too high development of whey acid injures the flavor as well as the texture of the curd.

2. The development of acid in the matted curd overcomes gas and bad taints and does not injure the flavor and texture.

3. Cheese with high acid should be put into cold storage as early as possible to minimize the bad effect of the acid.

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